

## DISCUSSION

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### ON FEYERABEND'S VERSION OF 'MACH'S THEORY OF RESEARCH AND ITS RELATION TO EINSTEIN'<sup>1</sup>

RECENTLY, the network of interactions around the 'philosopher – scientist' Ernst Mach and especially his contested influence on Einstein have acquired new interest on account of several studies in which a revision of the 'received versions' concerning the "Mach – Einstein episode" has been attempted.<sup>2</sup> Paul K. Feyerabend has proposed among some "lessons to be learned" that "one cannot trust received opinions or received versions of great turning points of science",<sup>3</sup> and started his program of elimination of 'incorrect', and 'simple-minded' legends in the history of science with a new reconstruction of the "battle about Mach and positivism: a net of confusions."<sup>4</sup>

(1) Even if Feyerabend does not cite any of the papers in which such concocted "misunderstandings and oversights"<sup>5</sup> take place, it is clear from the context that he is referring to studies of the so-called (neo-) positivists (for instance Petzoldt<sup>6</sup> or Hering<sup>7</sup>) in which the influence of Mach on Einstein was regarded as a triumph of empiricism and an anti-metaphysical attitude in scientific affairs

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<sup>2</sup>P. K. Feyerabend, 'Mach's theory of research and its relation to Einstein', *Studies in the History and Philosophy of Science*, 15 (1984), 1 – 22 (= F-1984 in the following citations).

<sup>3</sup>Apart from F-1984, for instance: Elie Zahar, 'Mach, Einstein and the rise of modern science', *Br. J. Philosophy of Sci.*, 28 (1977), 195 – 213; P. K. Feyerabend, 'Zahar on Mach, Einstein and modern science', *ibid.*, 31 (1980), 273 – 282; William B. Jones, 'The significance of Ernst Mach's thought for science and the philosophy of science', *Akten des III. Int. Wittgenstein-Symposiums* (Kirchberg/Wechsel, Wien, 1979), p. 330 – 331 (= Jones, 1979); Zeljko Loparic, 'Problem-solving and theory-structure in Mach', *Studies in the History and Philosophy of Science*, 15 (1984), 23 – 49.

<sup>4</sup>F-1984, p. 22.

<sup>5</sup>F-1984, p. 15.

<sup>6</sup>F-1984, p. 22.

<sup>7</sup>Josef Petzoldt, *Die Stellung der Relativitätstheorie in der geistigen Entwicklung der Menschheit* (Dresden, 1921), esp. p. 75ff and p. 92ff.; J. Petzoldt, *Das Verhältnis der Machschen Gedankenwelt zur Relativitätstheorie* (= appendix in the 8th edition of Ernst Mach, *Die Mechanik in ihrer Entwicklung historisch-kritisch dargestellt* (Leipzig, 8 1921) (= M<sup>8</sup>1883), pp. 490 – 517).

<sup>8</sup>H. E. Hering, 'Mach als Vorläufer des physikalischen Relativitätsprinzips', *Kölner Universitätszeitung*, 17 (1) (1920), 3 – 4.

and to later papers in which this point of view is adopted.<sup>8</sup> Feyerabend seems to have overlooked the fact that his claim to reject all ill- or badly justified opinions and to eliminate irrational fairy-tales itself reflects a positivist's plea for 'clarification' resulting in a pre-supposed adequacy of one and only one version.<sup>9</sup> Moreover, that such a vilified though non-defined form of 'positivism' has penetrated into his argumentation is demonstrable, for instance, in the light of Feyerabend's plea for a distinction between Mach's 'physical arguments' and his 'epistemology',<sup>10</sup> because it is precisely Feyerabend's phantom of 'positivism' that aims at such a demarcation between 'hard science' and 'metaphysical background'.<sup>11</sup>

(2) In contrast to Feyerabend's opinion that such "a separation is not difficult to achieve",<sup>12</sup> it is argued here that this approach is objectionable on two grounds:

(a) Mach's contributions to physics, physiology and philosophy (in a broad sense, including general statements on ontological and epistemological problems,<sup>13</sup> have common roots in very basic opinions including especially the following:<sup>14</sup>

#### *Ontological phenomenalism*

'Existence' could legitimately be claimed for ideas and sensations only, including relations among these but excluding nonsensational entities.

#### *Referential phenomenalism*

A 'meaningful reference' is possible and legitimate only in respect of what can (in principle) be consciously experienced.

<sup>8</sup>See, e.g., H. Goenner, 'Mach's principle and Einstein's theory of gravitation', *Boston Studies in the Philosophy of Science*, 6 (1970), 200–216; it should be mentioned however, that it was the alleged 'neopositivist' Hans Reichenbach, who pointed out as early as 1921 in his study 'Der gegenwärtige Stand der Relativitätsdiskussion' (first published in *Lotos* (Prag), Vol. 10 (1921), reprinted in *Gesammelte Werke*, 3, 342–405), that there are several concurring conceptions with different emphases and thereby realized the complexity of the Mach–Einstein relation and the plurality of mutually incompatible interpretations of Mach (see pp. 354–367 of the reprint).

<sup>9</sup>It is astonishing that Feyerabend, who pleads for a pluralism of different scientific models and theories, dealing with one and the same complex of problems in a mutually incompatible way, now believes in the sole adequacy of his perspectively distorted view. (Compare his *Wider den Methodenzwang. Skizze einer anarchistischen Erkenntnistheorie* (Frankfurt, 1976) (= F-1976), p. 371.)

<sup>10</sup>F-1984, p. 1.

<sup>11</sup>The search for a demarcation criterion and the different versions proposed is one of the themes of (neo)positivism, reappearing at all stages of evolution.

<sup>12</sup>F-1984, p. 1.

<sup>13</sup>Condensed in Ernst Mach, *Die Analyse der Empfindungen und das Verhältnis des Physischen zum Psychischen* (Jena<sup>5</sup> 1906) (= M<sup>1</sup>1886); E. Mach, *Erkenntnis und Irrtum. Skizzen zur Psychologie der Forschung* (Leipzig<sup>3</sup> 1917) (= M<sup>2</sup>1905) and completed by relevant chapters in E. Mach, *Die Principien der Wärmelehre, historisch-kritisch entwickelt* (Leipzig<sup>2</sup> 1900) (= M<sup>1</sup>1896) and E. Mach, *Populärwissenschaftliche Vorlesungen* (Leipzig<sup>3</sup> 1923) (= M<sup>3</sup>1895).

<sup>14</sup>A slightly different survey is given by J. T. Blackmore in *Ernst Mach. His Life, Work, and Influence* (Berkeley et al., 1972), p. 31 ff. (= Blackmore-1972).

*Biologism/pragmatism*

Knowledge in general, and scientific knowledge as its natural extension, are means of orientation in complex surroundings by means of complexity-reducing descriptions couched in terms of functional relations.

*'Theory – conventionalism' and 'economy of thought'*

Scientific theories aim at "uniform adaptations of thoughts (ideas) to facts (sensations) and of the thoughts one to another".<sup>15</sup> This 'economical' description of factual regularities involves the introduction of terms without direct reference, which are interpreted as theoretical constructs with provisional, descriptive value.<sup>16</sup>

Mach's early research into shock-waves (c. 1880), especially his use of Tóepler's striation method resulting in the first clear photographs demonstrating how shock waves look,<sup>17</sup> as well as his interferometer studies in collaboration with his son Ludwig towards the end of his life<sup>18</sup> were undertaken in consequence of his basic aim of providing visual evidence for theoretical, 'abstract' concepts.<sup>19</sup> Furthermore, in sharp contrast to Feyerabend's opinion that "Mach the physicist criticized absolute space without ever leaving the domain of physics"<sup>20</sup> it is argued here that it was exactly the premise of the above-mentioned two types of phenomenalism and economy of thought which formed the central part of Mach's criticism of Newton's doctrine, in his celebrated 'Mechanik in ihrer Entwicklung historisch-kritisch dargestellt'.<sup>21</sup> The reason for Mach's well-known thesis that for him only relative motion exists(!)<sup>22</sup> is clearly the epistemological fact that absolute motions are non-observable (conceded even by Newton for the case of uniform straight-line motion);<sup>23</sup> the substitution of 'fixed-star masses' for 'absolute space',<sup>24</sup> as well as his redefinition of mass as quotient of force

<sup>15</sup>English paraphrase of the title of chapter 10 in M<sup>1</sup>1905.

<sup>16</sup>The rejection by Ernst Mach of nineteenth century atomism as a realistically interpreted theory is one of the immediate consequences of this premise. Feyerabend's treatment of Mach's point of view is acceptable but remains within the familiar lines of the secondary literature; compare for instance: Blackmore-1972, p. 319ff; E. N. Hiebert, 'The genesis of Mach's early views on atomism', *Boston Studies in the Philosophy of Science*, 6 (1970), 79 – 106.

<sup>17</sup>Compare e.g. Blackmore-1972, pp. 105 – 115 and R. J. Seeger, 'On Mach's curiosity about shock-waves', *Boston Studies in the Philosophy of Science*, 6 (1970), 60 – 68.

<sup>18</sup>Compare Blackmore-1972, p. 280ff and appendices in: J. T. Blackmore/K. Hentschel (ed.), *Ernst Mach als Außenseiter. Machs Briefwechsel über Philosophie und Relativitätstheorie mit Persönlichkeiten seiner Zeit. Aurtug (Faksimile) aus dem letzten Notizbuch von Ernst Mach*, Braumüller, Wien 1985 (= Blackmore/Hentschel).

<sup>19</sup>This interpretation agrees with H. Henning, *Ernst Mach als Philosoph, Physiker und Psycholog* (Leipzig, 1915, esp. p. 57ff and p. 86ff).

<sup>20</sup>F-1984, p. 1.

<sup>21</sup>See note 6, M<sup>1</sup>1883, esp. pp. 191 – 268 (Chapter 2, Parts 3 – 8).

<sup>22</sup>M<sup>1</sup>1883, p. 248 (middle of Part 6 in §6).

<sup>23</sup>Isaac Newton, *Philosophia Naturalis Principia Mathematica*, first edition 1687, where uniform straight line motion and rest are treated as being dynamically equivalent, with respect to state-discerning forces.

<sup>24</sup>M<sup>1</sup>1883, p. 248f (§8 of Part 6).

and acceleration,<sup>25</sup> clearly are consequences of Mach's referential phenomenalism in which terms with demonstrable referent are preferred to non-referential concepts. His general remarks on the relationship between Ptolemy's and Copernicus' theories<sup>26</sup> as well as his emphasis on the provisional nature of even the simplest principles in mechanics<sup>27</sup> have to be traced back to Mach's doctrine of economy of thought, as the only and temporally restricted decision-criterion between empirically equivalent theories.

As historical support for my claims concerning the basically philosophical character of Mach's argumentation I may add that it was a similar constellation of such general premises concerning 'metaphysical matters' in George Berkeley's philosophy (*esse est percipi*), which as early as 1720 prompted the Irish Bishop into arguments astonishingly similar to some of Mach's.<sup>28</sup>

(b) In addition to these arguments derived from activities and statements of Mach in the context of the exact sciences and the psychological implausibility of an analytic split between physical arguments and 'epistemology' in Mach's oeuvre (who loved to intermingle both types of discourse<sup>29</sup>) there are sources which explicitly demonstrate that he would have disliked such a treatment of his writings.

In an unpublished letter to Wilhelm Ostwald dated 23 July 1913, Mach, for example, writes the following:

The two main faults: formally unsatisfactory representation of the monistic philosophy, and the spurious advance on acknowledgment of my point of view by the official physics, are well known to me. Concerning the first, I'm confident enough given good intellectual mood — humour alone is not enough in this respect — to be able to eliminate it completely. To alter the second fault is not in my control, since I can only offer my opinion, but cannot impose it upon the physicist or the philosophers.<sup>30</sup>

<sup>25</sup>M<sup>1</sup>1883, p. 246, p. 258f.

<sup>26</sup>M<sup>1</sup>1883, p. 242 (§5 of Part 6).

<sup>27</sup>See, e.g., M<sup>1</sup>1883, p. 510ff, p. 82ff (Chapter 4, Part 4 and Chapter 1, Part 5) and M<sup>1</sup>1896 ('On transformation and adaptation in scientific reasoning').

<sup>28</sup>See George Berkeley, *De Motu*, English translation in: *The Works of G. Berkeley, Bishop of Cloyne*, A. A. Luce and T. E. Jessop (eds) (London, 1949); German translation in *Schriften über die Grundlagen der Mathematik und Physik*, W. Breidert (ed.) Frankfurt (1969); see also: K. R. Popper, 'A note on Berkeley as precursor of Mach and Einstein', in *Conjectures and Refutations* (London, 1965), Chapter 6; and J. Myhill, 'Berkeley's 'de motu' — an anticipation of Mach', *University of California Publications*, 29 (1957), 141–157.

<sup>29</sup>See for instance his *Mechanik* (M-1883) and the introduction as well as chapter four, part four therein or his *Wärmelehre* (M-1896) and Chapters 22–34 therein. The diffusion of his *Popular Lectures* (M-1895) can be regarded as a result of this unity of representation.

<sup>30</sup>German original from: Zentrales Akademie-Archiv. Wilhelm-Ostwald-Gedenkstätte, Großbothen. My thanks go to Dr. Stilp of the Ernst-Mach-Archiv der Fraunhofer-Gesellschaft, Freiburg for the permission to cite this paraphrase of Mach's unpublished letter.

Perhaps Feyerabend would argue at this point that there are passages, in which Mach himself explicitly denied being a 'philosopher'<sup>31</sup> — but all these passages are merely rejections of the traditional role of the 'philosopher' and they are consistent with my assertion of a fundamental unit of 'philosophical' and 'scientific' premises and implications in Mach's work.<sup>32</sup> As a corroboration of this I may cite part of an up to now unpublished letter of Ernst Mach to Harald Höffding, dated 6 September 1905:

I was very pleased that you count me among 'philosopher – scientists' [philosophierende Naturwissenschaftler] and not among 'philosophers'. My aim and my profession is not to solve philosophical problems, but only to purify the methodology of the natural sciences from old disturbing pseudoproblems.<sup>33</sup>

Clearly the latter is a philosophical (epistemological) task in the sense of twentieth-century philosophy with scientific (physical) implications. Therefore, it was by no means an accident, that the Vienna and Berlin circles of logical empirism traced their programmatic search for 'unity of science' back to Ernst Mach.<sup>34</sup>

(3) Feyerabend's versions of Mach's theory of research certainly is adequate insofar as he emphasizes the importance of 'dynamics of theory' as well as the complexity of Mach's account of scientific knowledge; whether it is fair to achieve this vindication by means of condemning Einstein as "talking positivism"<sup>35</sup> will be discussed in the next section. Certainly Mach was no naive inductivist<sup>36</sup> and he certainly sought to integrate the use of principles involved in research, despite their tentative character.<sup>37</sup> Nevertheless Feyerabend tends to over-emphasize passages selected from Mach's 'Mechanik':<sup>38</sup> whilst Mach acknowledged the use of principles and knew about the importance of purely intuitive thought, the systematic place for this sort of scientific activity in Mach's theory of research is that of heuristics; to rely on instinctive intuitions is called

<sup>31</sup>See for instance 'Foreword' to the fourth edition of M-1886, p. IX and the famous foreword to M<sup>2</sup>1905, p. V and VII.

<sup>32</sup>This thesis has been put forward in almost all earlier books on Mach (see esp. Blackmore-1972); see also Mach's explicit statements in M-1886, p. VII (foreword to the second edition) or in M<sup>2</sup>1905, p. VIII.

<sup>33</sup>See note 30; from Kongelige Bibl., Kopenhagen. Complete letter in: Blackmore/Hentschel, No. 30.

<sup>34</sup>Compare for instance 'Appendices' by Philipp Frank and R. v. Mises in *Boston Studies in the Philosophy of Science*, 6 (1970), 219ff; the contributions by E. Lesky, F. von Hayek and J. Thiele in *Symposium aus Anlaß des 50. Todestages von Ernst Mach*, Freiburg (1966); J. Thiele, *Die Bedeutung Ernst Machs für die Wende von der klassischen zur modernen Physik. Ein Beitrag zur vergleichenden Geschichte wissenschaftstheoretischer Systeme*, Dissertation Hamburg (1959); Fr. Stadler, *Vom Positivismus zur 'wissenschaftlichen Weltauffassung'* (Wien, 1982) and further sources cited therein.

<sup>35</sup>F-1984, p. 1.

<sup>36</sup>Compare F-1984, part 2.

<sup>37</sup>Compare F-1984, part 1; see Jones-1979 for similar points.

<sup>38</sup>See note 6 and M<sup>1</sup>1883, p. 31ff (Chapter 1, Part 2).

'Grundbedingung für das Entstehen dieser Erkenntnisse'<sup>39</sup> [fundamental precondition for the *genesis* of that kind of knowledge] — that is: not for their *justification*. Consider, for instance, the sentence cited by Feyerabend:<sup>40</sup> "Ja, es ist sogar gewiß, dass nur die Verbindung des stärksten Instinktes mit der größten begrifflichen Kraft den großen Naturforscher ausmacht", which, however, continues (unfortunately not cited by Feyerabend!): "Dies nötigt uns aber keineswegs, aus dem Instinctiven in der Wissenschaft eine neue Mystik zu machen und dasselbe etwa für unfehlbar zu halten . . . Selbst instinctive Erkenntnisse von so großer logischer Kraft wie das von Archimedes verwendete Symmetrieprinzip können irreführen."<sup>41</sup>

For similar reasons, I can't agree with Feyerabend's claim that "the very same kind of principles which neo-Kantians tried to establish in an *a priori* manner were discussed and recommended by Mach who based them on instinct".<sup>42</sup> In his discourse on the geometry of space for instance, Mach in no way opposes the use of higher-dimensional geometries (as most Kantians did!) as hypothetical, symbolic representations. Mach's only argument for the preference of the Euclidean version was its comparative 'simplicity' and the lack of any need to alter its presuppositions (resp. axioms).<sup>43</sup> The 'geometrical instinct' which is mentioned once<sup>44</sup> is quoted only in the context of the retrospective, psychological explanation of the behaviour of elder scientists such as Saccheri or Lambert who (as Mach claims) intuitively adopted criteria of 'Denkökonomie' [the economy of thought] which were made explicit in Mach's methodology.

Similarly, in calling Mach's theory of research 'dialectical rationalism'<sup>45</sup> Feyerabend misses the mark because that term ignores the phenomenalist core of Mach's argumentation. As a whole, Feyerabend's statements on Mach are therefore likely to create new confusions and at the very least have questionable weight in their aim of eliminating some of older erroneous views.<sup>46</sup>

(4) Feyerabend's treatment of *Einstein's epistemology* again suffers from the distortions in his interpretation of Mach. Of course, Mach as well as Einstein believed in a strong bond between science and common-sense, and of course Einstein as well as Mach included an element of 'scientific instinct' in their

<sup>39</sup>*ibid*, p. 30.

<sup>40</sup>See F-1984, p. 2 for the English translation.

<sup>41</sup>"This does not compel us to create a new mysticism concerning the instinctive elements in science, and to regard them as something unalterable. . . even instinctive knowledge with logical force as Archimedes' principle of symmetry can lead astray" (my translation from the German original). And even at the very beginning of the *Mechanik*, Mach uses the words 'instinctive' and 'non-developed' (undurchgebildet, zufällig gefunden) as synonymous; see M<sup>2</sup>1883, p. 2.

<sup>42</sup>F-1984, p. 4 annotation.

<sup>43</sup>See Mach's *Erkenntnis u. Irrtum*, (M<sup>2</sup>1905), Chapter 22 ('space and geometry. . .', p. 389ff).

<sup>44</sup>*ibid*, p. 414.

<sup>45</sup>F-1984, p. 11.

<sup>46</sup>Perhaps Feyerabend's treatment of Mach should be regarded as an example of his method of 'contra-induction', recommended by him in chapter 2 of F-1976. Nevertheless, his arguments won't contribute to the aim "die schwächere Seite zur stärkeren zu machen" (p. 49 *ibid.*) but only to create a new, untenable version in the 'battlefield'.

methodology.<sup>47</sup> Nevertheless, the way in which Feyerabend in part two of his paper attempts to construct the similarity between their respective recommended research procedures is not convincing. Einstein's postulate of the constancy of the velocity of light *in vacuo* as one of the main 'principles' of his 1905-paper<sup>48</sup> on the one hand, and Mach's recommendation of the reliance on intuitive principles as the starting point of scientific reasoning on the other, are not analogous: whilst the former is a formal postulate, comparable to a mathematical axiom, in that its justification is achieved only through the development of its consequences, Mach had principles in mind whose assumption is accompanied by some sort of experience of self-evidence.<sup>49</sup> Furthermore, in 1917 Einstein himself (still before his final turn against Mach<sup>50</sup>) wrote in a letter to M. Besso:

Über das Mach'sche Rösslein schimpf ich nicht; Du weisst doch, wie ich darüber denke. Aber es kann nichts Lebendiges gebären, sondern nur schädliches Gewürm ausrotten;<sup>51</sup>

thus sharply accentuating the *negative* impetus of Mach whom he subsequently praised for his scepticism and independence of judgement in his 'Mach obituary' of 1916.<sup>52</sup> Feyerabend's claim, that Einstein 'talked positivism' is either a misuse of this outworn term, 'positivism',<sup>53</sup> or incorrect since Einstein himself, for instance in his correspondence with Schlick, criticized the latter for his point of view which to Einstein seemed to be "too positivistic".<sup>54</sup>

(5) One last point: in his provocative "lessons to be learned", at the end of his paper, Feyerabend states<sup>55</sup> that "the faults of the received opinions can often

<sup>47</sup>See Einstein's relevant papers, collected e.g. in *Mein Weltbild*, (first edition Amsterdam, 1934), Ulm, 1977 and in *Aus meinen späteren Jahren* [Out of My Later Years], German edition Stuttgart, 1969; see also A. Einstein, 'Induktion und Deduktion in der Physik', *Berliner Tageblatt*, 48. Jg., 1919, Nr. 617, 25. XII. Suppl. 4.

<sup>48</sup>Reprinted in Lorentz u. Einstein u. Minkowski, *Das Relativitätsprinzip*, Stuttgart, 1974.

<sup>49</sup>See Mach's treatment of Archimedes', in his *Mechanik* (M<sup>1</sup>1883, p. 11ff.).

<sup>50</sup>Which has been described for instance by Gerald Holton, 'Mach, Einstein and the search for reality', in *Thematic Origins of scientific thought* . . . (Cambridge, Massachusetts, 1973) German translation *Thematische Analyse der Wissenschaft*. . . (Frankfurt, 1981), p. 203 – 254 (= Holton, 1981).

<sup>51</sup>A. Einstein – M. Besso: *Correspondence 1903 – 1955* (Paris, 1972) (ed.) P. Speziali, p. 114; "I do not complain about Mach's horse; you know how I think about it. It can't give birth to living beings but only destroy harmful worms" (5 May 1917 — my translation).

<sup>52</sup>A. Einstein, 'Ernst Mach', *Physikalische Zeitschrift*, 17 (1916), p. 101 – 104; reprint, e.g., in K. D. Heller, *Ernst Mach. Wegbereiter der modernen Physik* (Berlin et al., 1964), 151 – 157.

<sup>53</sup>Compare for instance the obscure, 'dialectic' arguments of Feyerabend on p. 17 of F-1984.

<sup>54</sup>Einstein to M. Schlick, 26 November 1930, cited completely and commented on in K. Hentschel, *Zum Verhältnis Philosophie-Physik anhand der Korrespondenz Schlick – Einstein und ergänzender Dokumente*, Magisterarbeit Universität Hamburg (1984), p. 165f (see also Holton-1981, p. 233); Einstein's charge against Schlick has again a rather ironic background, since Schlick, for instance in his *Allgemeine Erkenntnislehre* (1918/1925) regarded himself as a critic of 'positivism'.

<sup>55</sup>F-1984, p. 22; Feyerabend has also missed several important studies by Friedrich Herneck; see, e.g., 'Die Beziehungen zwischen Einstein und Mach, dokumentarisch dargestellt', *Wissenschaftliche Zeitschrift der Friedrich Schiller Universität Jena*, 15 (1966), 1 – 14 and papers cited therein.

be found without detailed archival studies — careful reading of a few well-known books suffices.’ It appears to me that the shortcomings and distortions in Feyerabend’s paper, discussed above, simply reflect his own very partial orientation. To claim that earlier scholarly versions of ‘great debates’ in the history of science are grown through with misunderstandings and oversights does not free one from the danger of producing fresh sorts of misunderstanding, perhaps ‘incommensurable’ with previous versions but certainly no great step forward.<sup>46</sup> “To rescue the participants from the fairy tales that are being told about them”<sup>56</sup> has usually meant pointing to documents unknown or not referred to previously. In this respect, the result of Feyerabend’s paper is therefore only the emphasis on Mach’s hitherto undervalued acknowledgement of ‘instinct’. Detailed archival studies (e.g. in the Ernst Mach Archiv der Fraunhofer – Gesellschaft, Freiburg, Breisgau, F.R.G.) might have helped Feyerabend to appreciate, for instance, the relevance of entries in unpublished notebooks in the last years of his life; proving that the personal contact between him and Einstein was more intensive than hitherto known,<sup>57</sup> or that questions of authenticity concerning the famous ‘Optik-foreword’ in the posthumous 1921-edition of ‘Die Optik . . .’<sup>58</sup> are not settled as yet altogether,<sup>59</sup> or that it would be better to study Mach’s commentaries on the theory of relativity in his extensive correspondence up to the last years of his life<sup>60</sup> rather than engage in vague speculations.

<sup>46</sup>*ibid.*

<sup>47</sup>See Appendix of Blackmore/Hentschel, note 18.

<sup>48</sup>Ernst Mach, *Die Prinzipien der physikalischen Optik, historisch und erkenntnispsychologisch entwickelt* (Leipzig, 1921; edited by Mach’s son Ludwig; reprinted Frankfurt, 1982).

<sup>49</sup>See for instance Gereon Wolters, ‘Diadochenkämpfe um das Erbe Machs: zum 100-jährigen Jubiläum der ‘Mechanik’, submitted to *Annals of Science*.

<sup>60</sup>A vast amount of hitherto unpublished letters to and from Mach will be collected in Blackmore/Hentschel, see note 18.